US009116454B2

(12) **United States Patent**
Iwanami et al.

(10) **Patent No.:** **US 9,116,454 B2**
(45) **Date of Patent:** **Aug. 25, 2015**

(54) **DENSITY DETECTION APPARATUS AND METHOD AND IMAGE FORMING APPARATUS**

(75) Inventors: **Toru Iwanami**, Kanagawa (JP); **Tomohisa Suzuki**, Kanagawa (JP); **Makoto Hamatsu**, Kanagawa (JP); **Wenxiang Ge**, Kanagawa (JP); **Kenjo Nagata**, Kanagawa (JP); **Hidefumi Tanaka**, Kanagawa (JP)

(73) Assignee: **FUJI XEROX CO., LTD.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 67 days.

(21) Appl. No.: **13/592,777**

(22) Filed: **Aug. 23, 2012**

(65) **Prior Publication Data**

US 2013/0201497 A1 Aug. 8, 2013

(30) **Foreign Application Priority Data**

Feb. 8, 2012 (JP) 2012-025518

(51) **Int. Cl.**
G06K 15/02 (2006.01)
H04N 1/52 (2006.01)
G03G 15/01 (2006.01)
G03G 15/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G03G 15/0189*** (2013.01); ***G03G 15/5058*** (2013.01)

(58) **Field of Classification Search**
CPC . G03G 5/00; G03G 15/0189; G03G 15/5058; G06F 1/00
USPC 358/1.1–1.9, 1.11–1.18
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,991,558	A *	11/1999	Emi et al.	399/49
6,185,007	B1 *	2/2001	Hayashi et al.	358/1.9
2005/0100356	A1 *	5/2005	Yang et al.	399/49
2008/0219682	A1 *	9/2008	Yamasaki et al.	399/16
2011/0182601	A1 *	7/2011	Nakatsuji et al.	399/49

FOREIGN PATENT DOCUMENTS

JP 04-146459 A 5/1992

* cited by examiner

Primary Examiner — King Poon
Assistant Examiner — Ibrahim Siddo
(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(57) **ABSTRACT**

A density detection apparatus includes the following elements. An image forming unit forms density detection images having different area ratios. A measuring unit measures an amount of reflected light. A storage unit stores reference values and also stores a representative value thereof. A determining unit determines a threshold for the area ratios of the density detection images on the basis of a variation among the reference values. A density obtaining unit obtains, for a density detection image having an area ratio which exceeds the threshold, a density level by using the amount of light reflected by the density detection image and the representative value, and obtains, for a density detection image having an area ratio which is equal to or smaller than the threshold, a density level by using the amount of light reflected by the density detection image, the associated reference value, and the representative value.

6 Claims, 10 Drawing Sheets

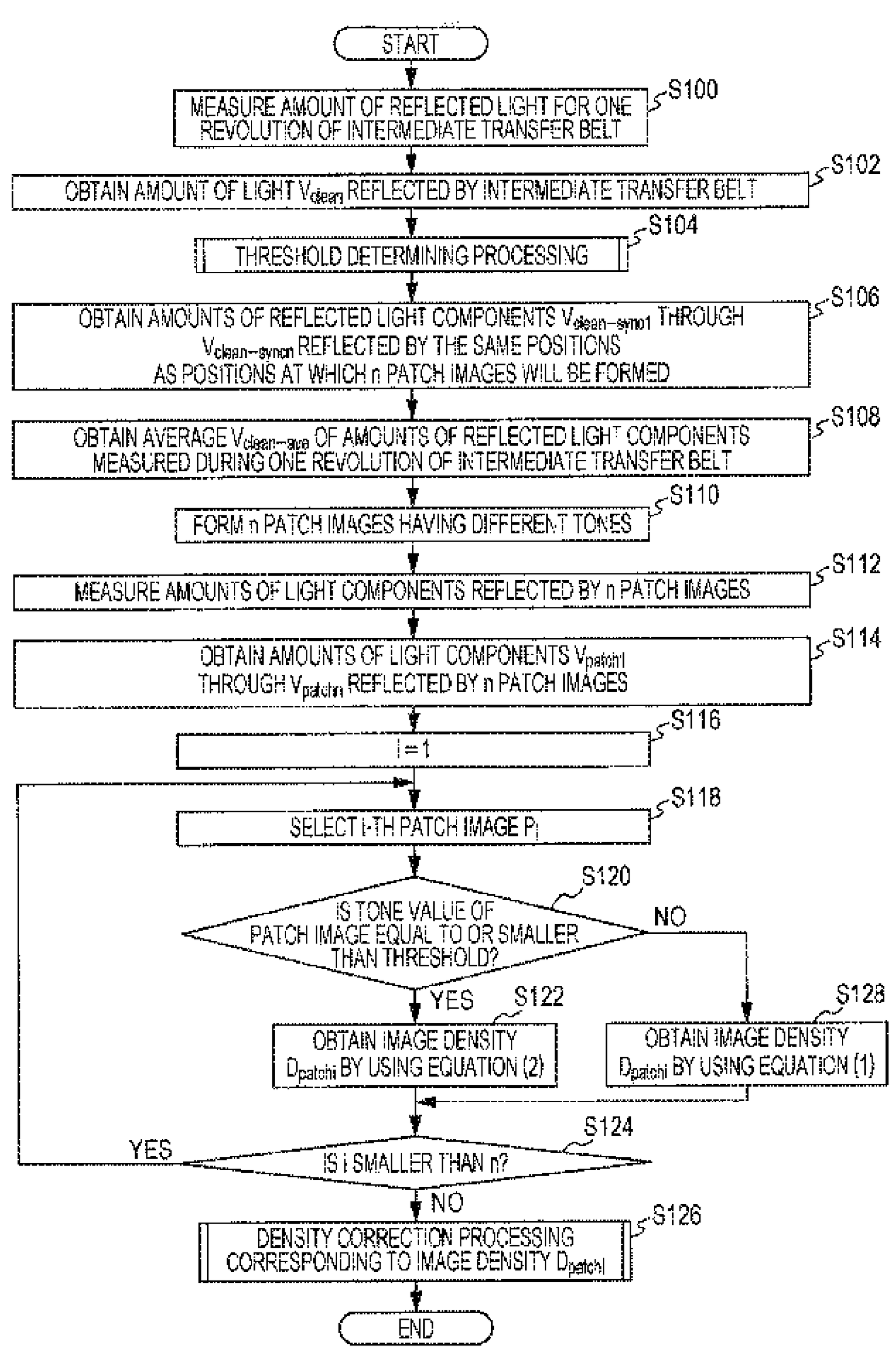


FIG. 1

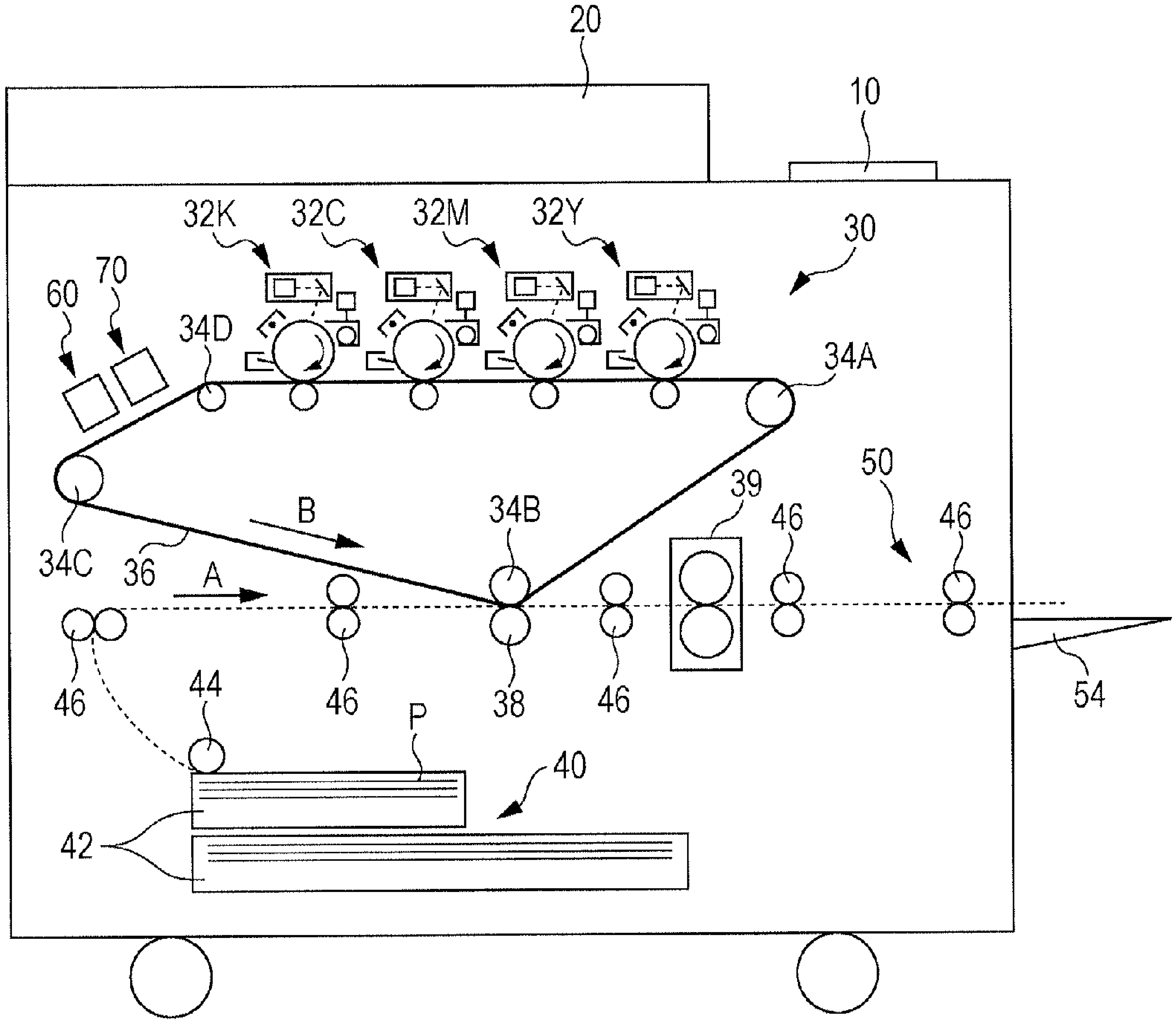

20
10
32K
32C
32M
32Y
30
60
70
34D
34A
50
39
46
46
B
34B
34C
36
A
46
46
38
46
54
44
P
40
42

FIG. 2

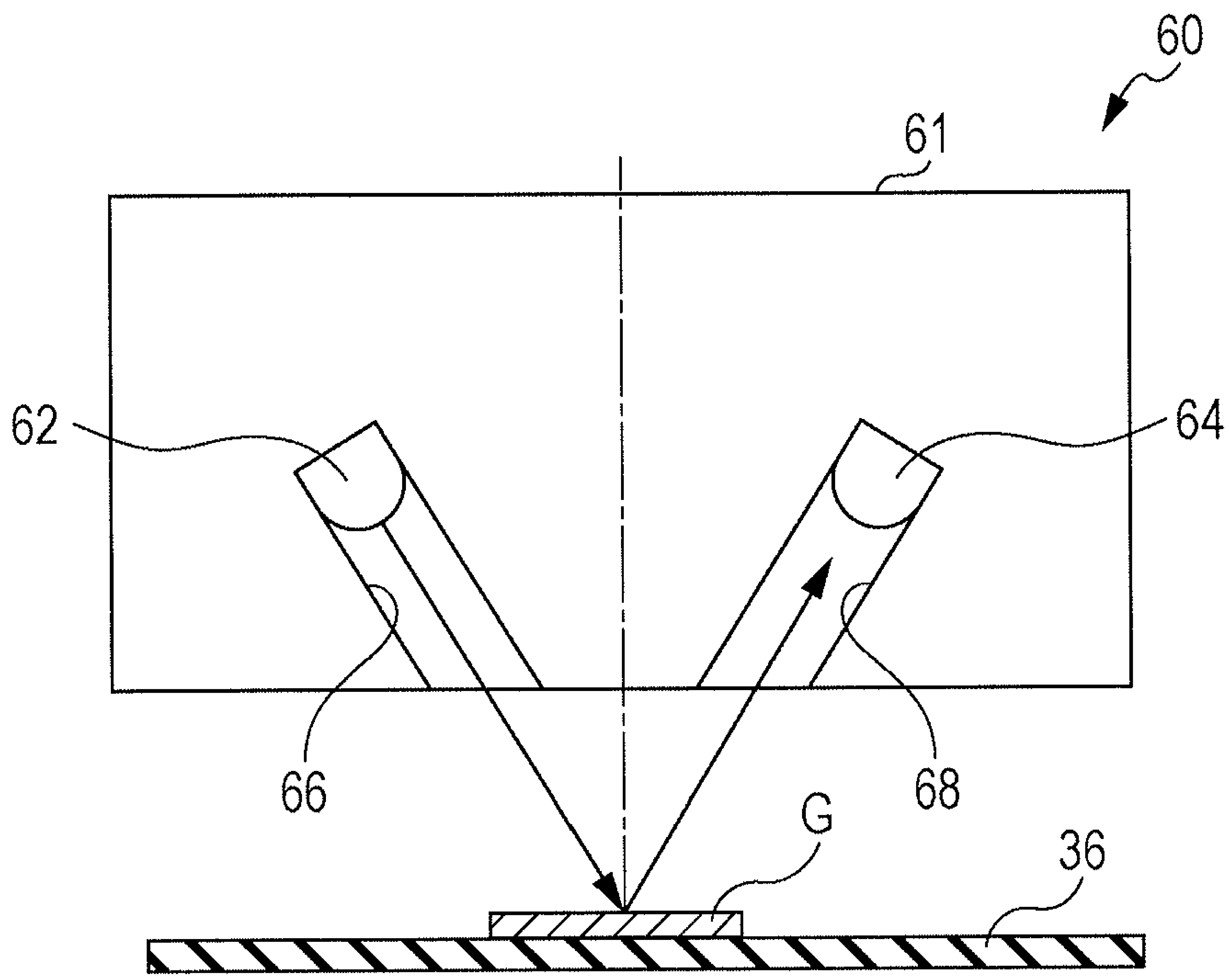


FIG. 3

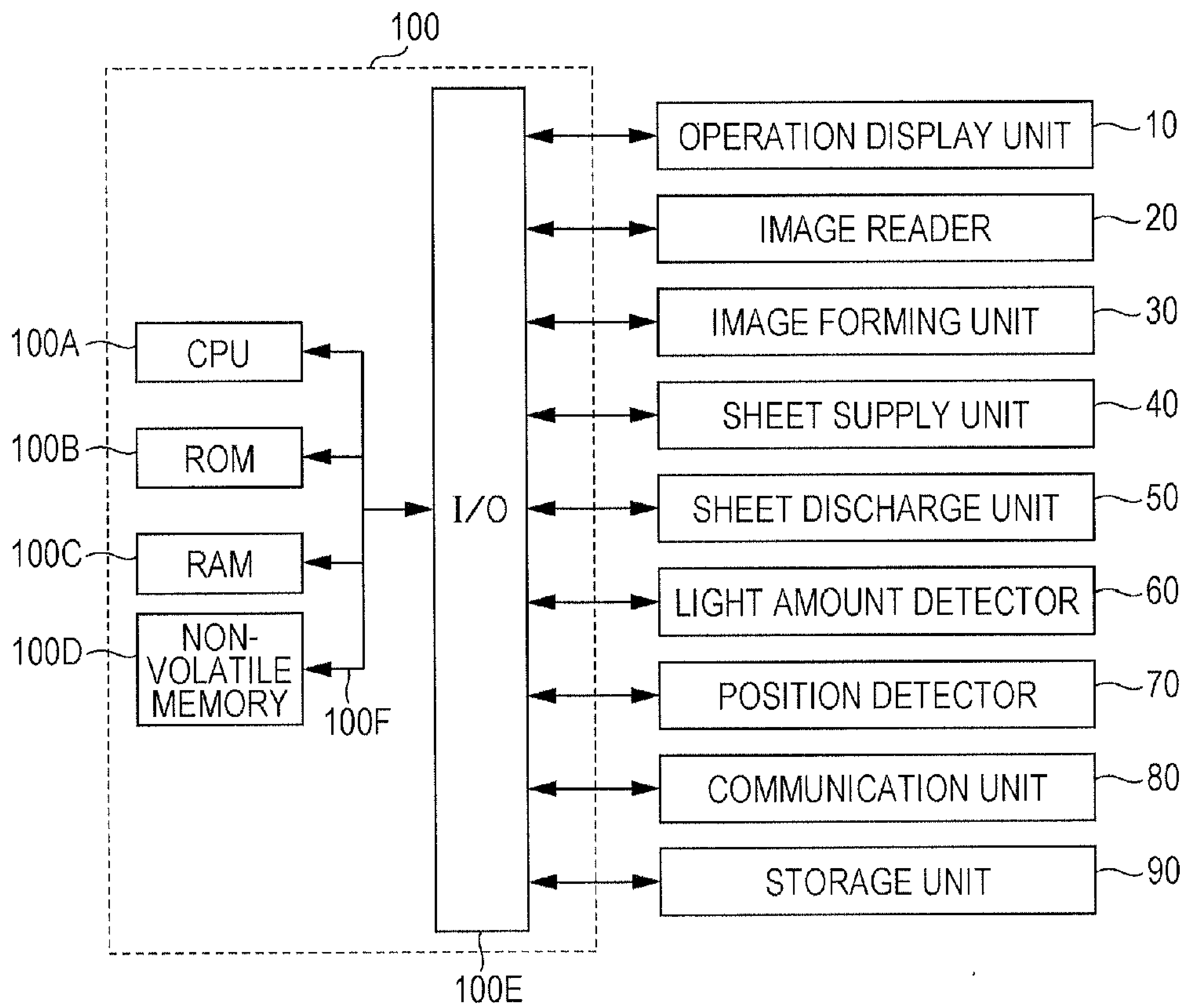

100
OPERATION DISPLAY UNIT
10
IMAGE READER
20
IMAGE FORMING UNIT
30
SHEET SUPPLY UNIT
40
SHEET DISCHARGE UNIT
50
LIGHT AMOUNT DETECTOR
60
POSITION DETECTOR
70
COMMUNICATION UNIT
80
STORAGE UNIT
90
100A
CPU
100B
ROM
100C
RAM
100D
NON-VOLATILE MEMORY
100F
I/O
100E

FIG. 4

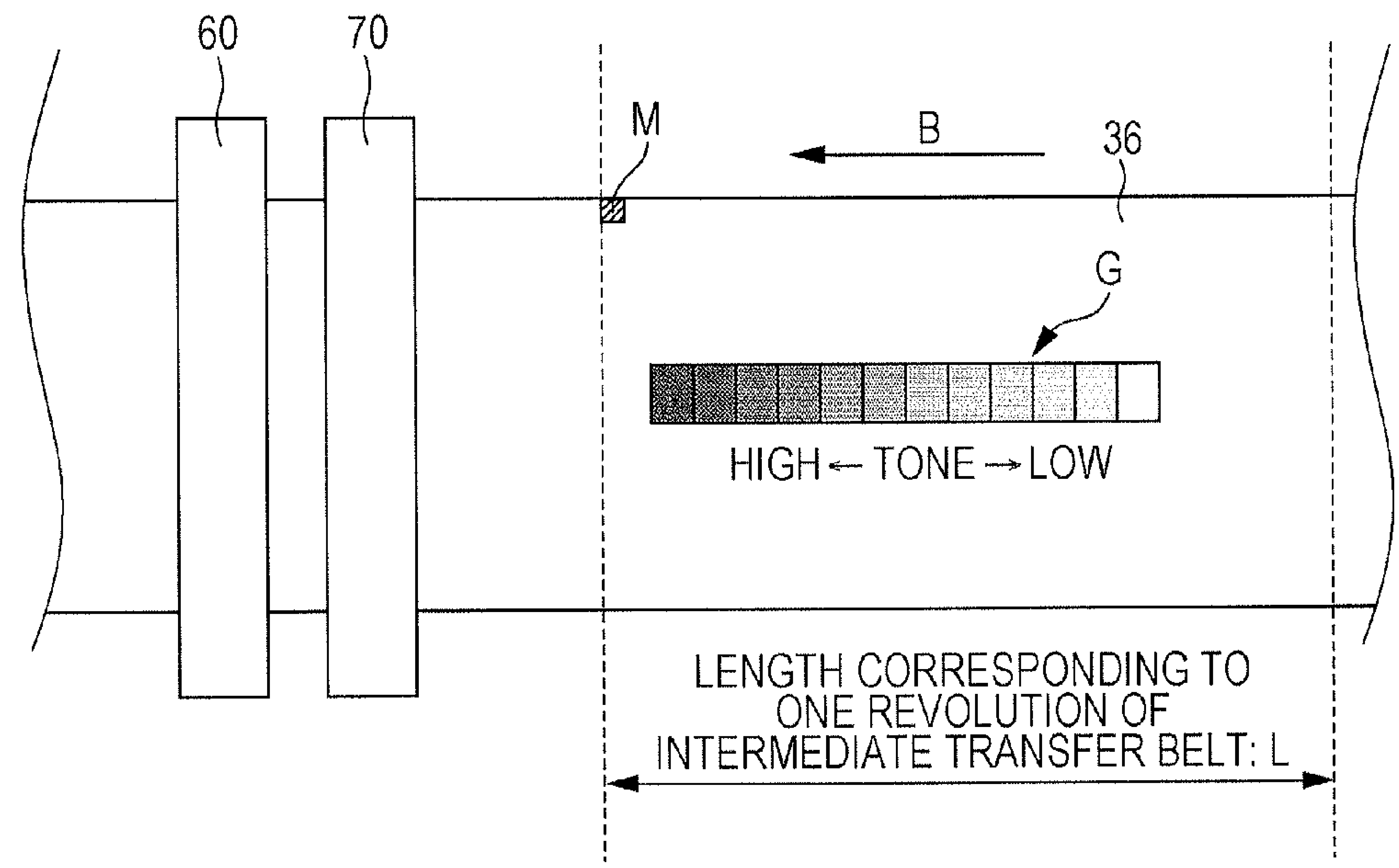

60
70
M
B
36
G
HIGH ← TONE → LOW
LENGTH CORRESPONDING TO
ONE REVOLUTION OF
INTERMEDIATE TRANSFER BELT: L

FIG. 5

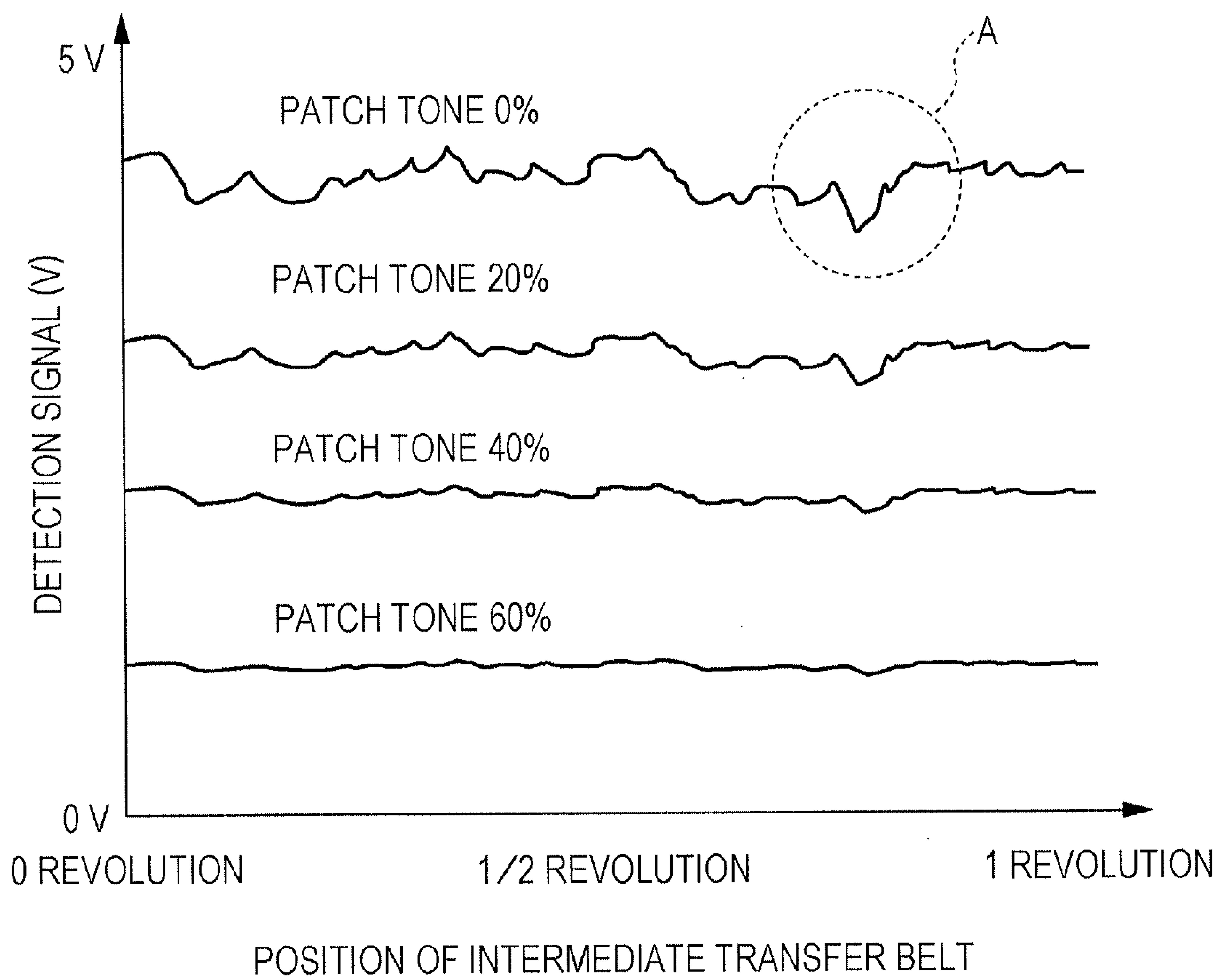

5 V
A
PATCH TONE 0%
PATCH TONE 20%
PATCH TONE 40%
PATCH TONE 60%
DETECTION SIGNAL (V)
0 V
0 REVOLUTION
1/2 REVOLUTION
1 REVOLUTION
POSITION OF INTERMEDIATE TRANSFER BELT

FIG. 6

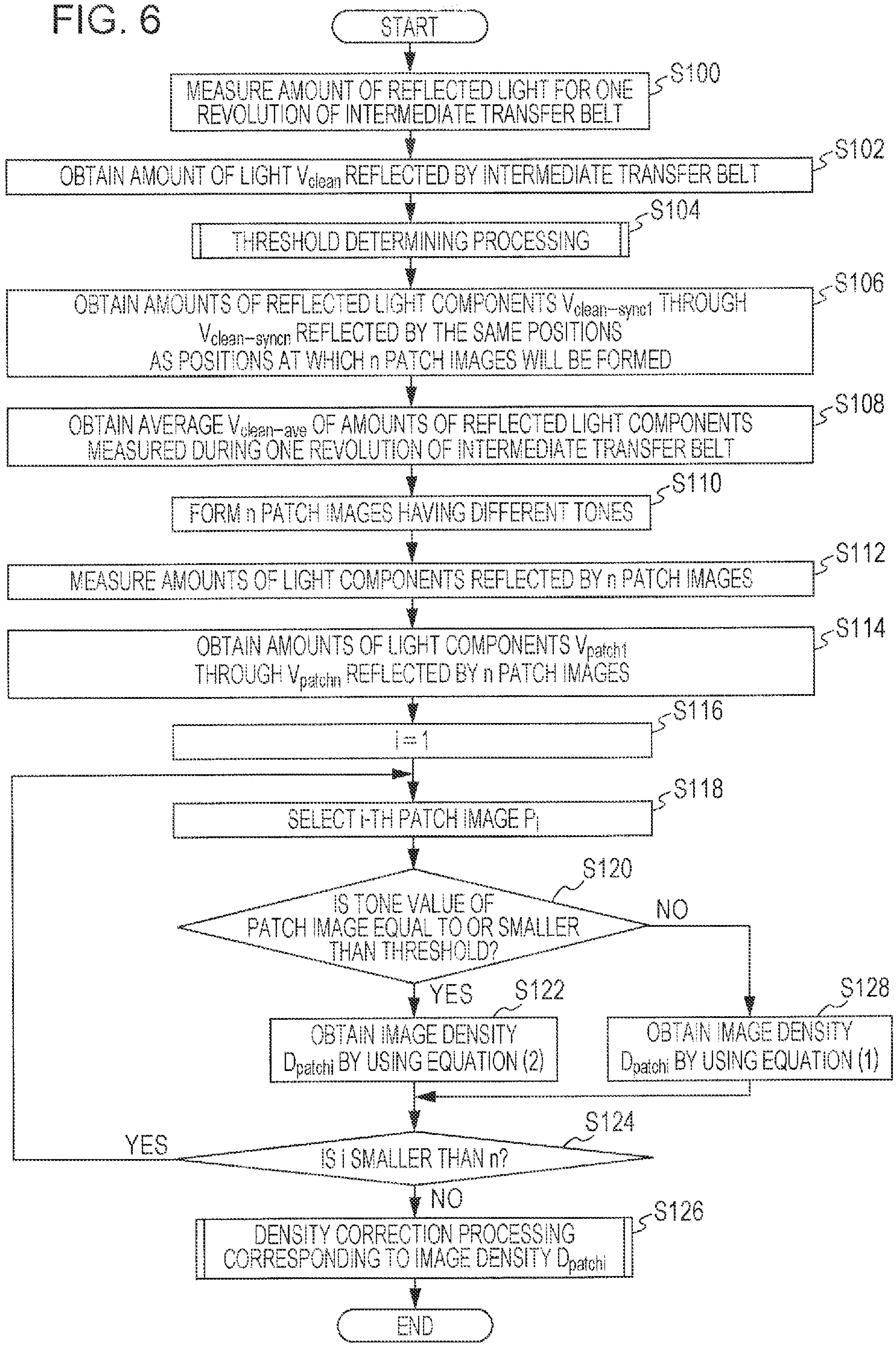

START
MEASURE AMOUNT OF REFLECTED LIGHT FOR ONE REVOLUTION OF INTERMEDIATE TRANSFER BELT
S100
OBTAIN AMOUNT OF LIGHT V_{clean} REFLECTED BY INTERMEDIATE TRANSFER BELT
S102
THRESHOLD DETERMINING PROCESSING
S104
OBTAIN AMOUNTS OF REFLECTED LIGHT COMPONENTS $V_{clean-sync1}$ THROUGH $V_{clean-syncn}$ REFLECTED BY THE SAME POSITIONS AS POSITIONS AT WHICH n PATCH IMAGES WILL BE FORMED
S106
OBTAIN AVERAGE $V_{clean-ave}$ OF AMOUNTS OF REFLECTED LIGHT COMPONENTS MEASURED DURING ONE REVOLUTION OF INTERMEDIATE TRANSFER BELT
S108
FORM n PATCH IMAGES HAVING DIFFERENT TONES
S110
MEASURE AMOUNTS OF LIGHT COMPONENTS REFLECTED BY n PATCH IMAGES
S112
OBTAIN AMOUNTS OF LIGHT COMPONENTS V_{patch1} THROUGH V_{patchn} REFLECTED BY n PATCH IMAGES
S114
i = 1
S116
SELECT i-TH PATCH IMAGE P_i
S118
IS TONE VALUE OF PATCH IMAGE EQUAL TO OR SMALLER THAN THRESHOLD?
S120
NO
YES
OBTAIN IMAGE DENSITY D_{patchi} BY USING EQUATION (2)
S122
OBTAIN IMAGE DENSITY D_{patchi} BY USING EQUATION (1)
S128
IS i SMALLER THAN n?
S124
YES
NO
DENSITY CORRECTION PROCESSING CORRESPONDING TO IMAGE DENSITY D_{patchi}
S126
END

FIG. 7

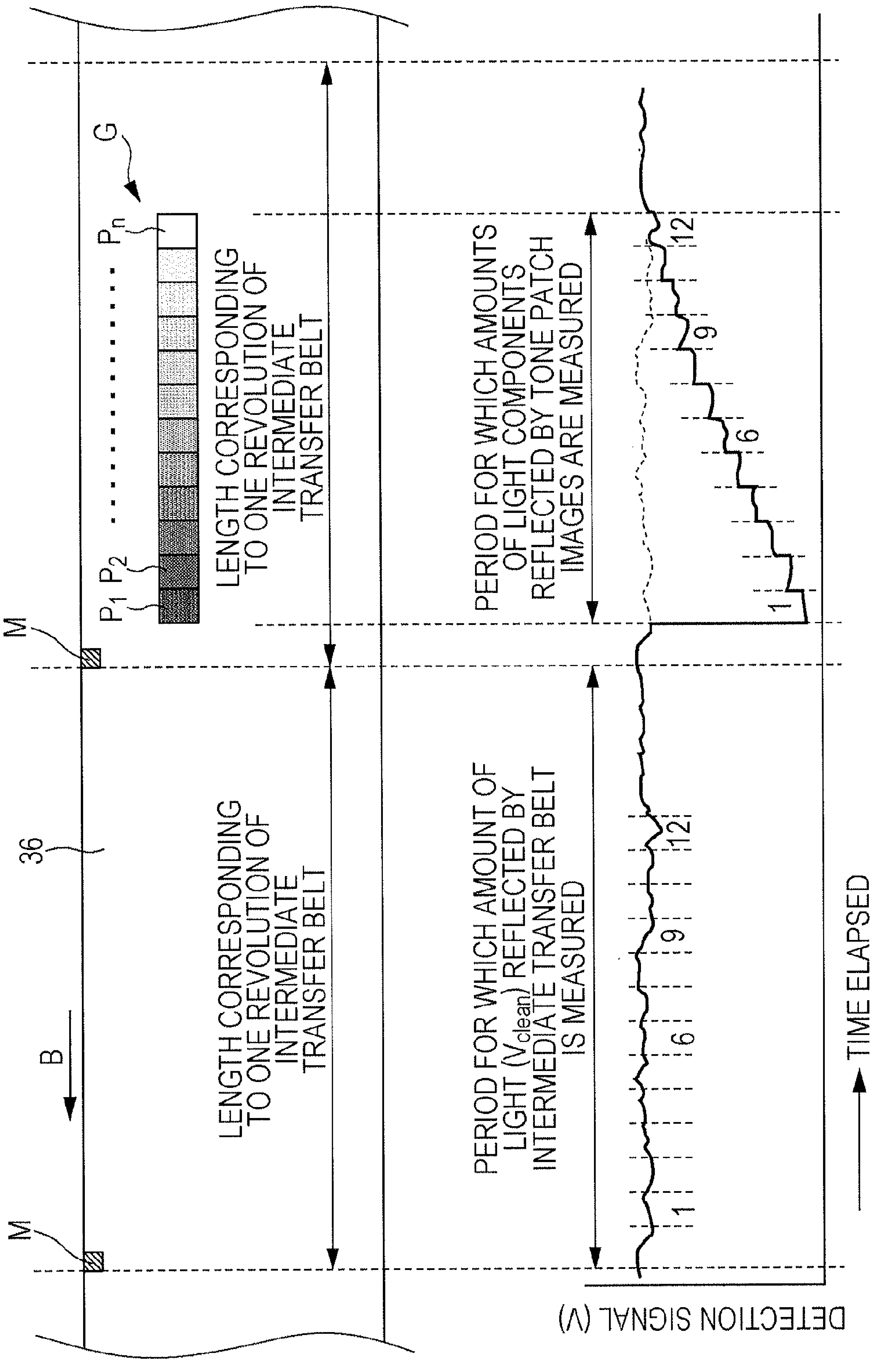

G
P_n
P_1 P_2
M
36
B
M
LENGTH CORRESPONDING TO ONE REVOLUTION OF INTERMEDIATE TRANSFER BELT
LENGTH CORRESPONDING TO ONE REVOLUTION OF INTERMEDIATE TRANSFER BELT
PERIOD FOR WHICH AMOUNTS OF LIGHT COMPONENTS REFLECTED BY TONE PATCH IMAGES ARE MEASURED
PERIOD FOR WHICH AMOUNT OF LIGHT (V_{clean}) REFLECTED BY INTERMEDIATE TRANSFER BELT IS MEASURED
1
6
9
12
1
6
9
12
DETECTION SIGNAL (V)
TIME ELAPSED

FIG. 8

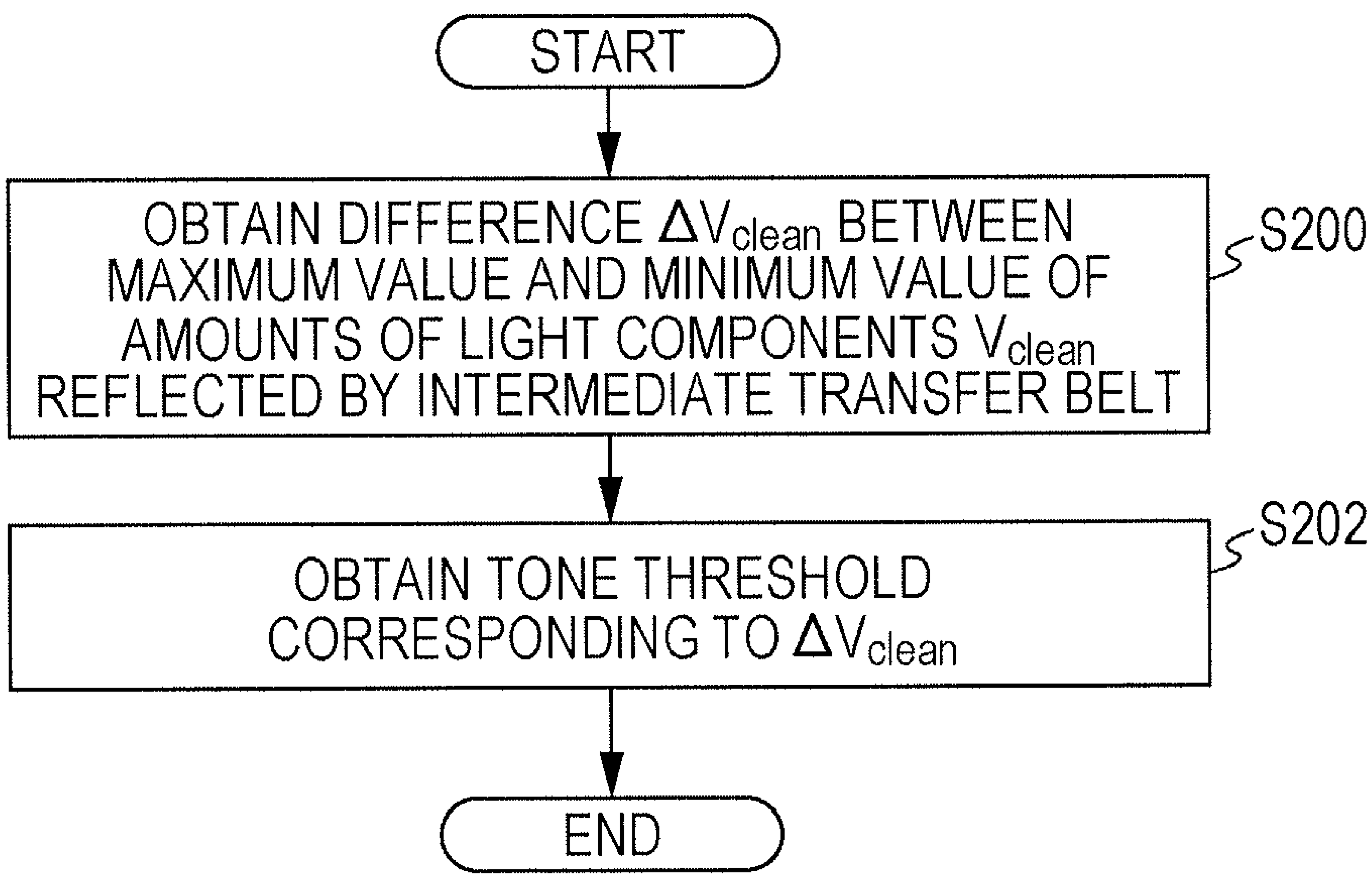

START
OBTAIN DIFFERENCE ΔVclean BETWEEN MAXIMUM VALUE AND MINIMUM VALUE OF AMOUNTS OF LIGHT COMPONENTS Vclean REFLECTED BY INTERMEDIATE TRANSFER BELT
S200
OBTAIN TONE THRESHOLD CORRESPONDING TO ΔVclean
S202
END

FIG. 9A

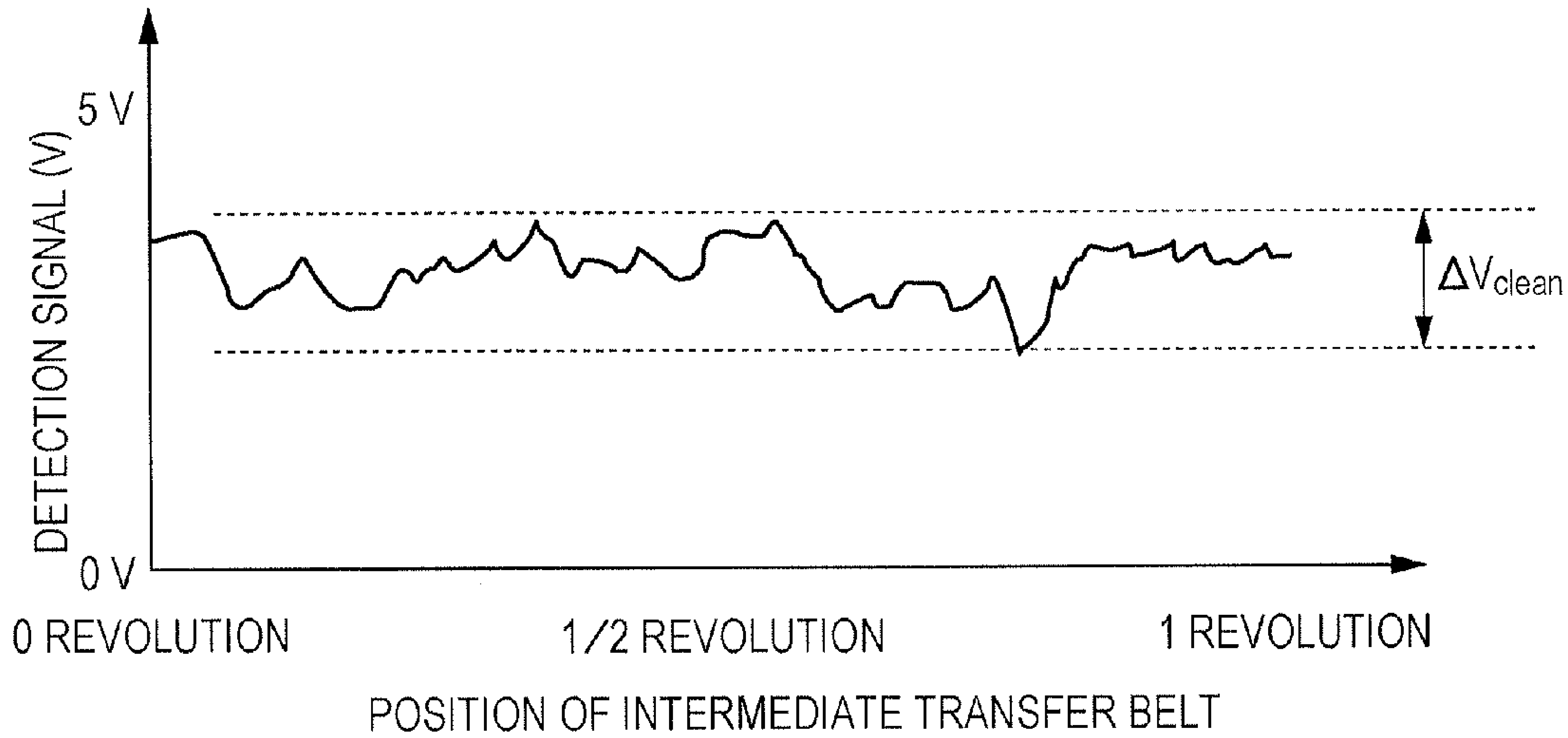
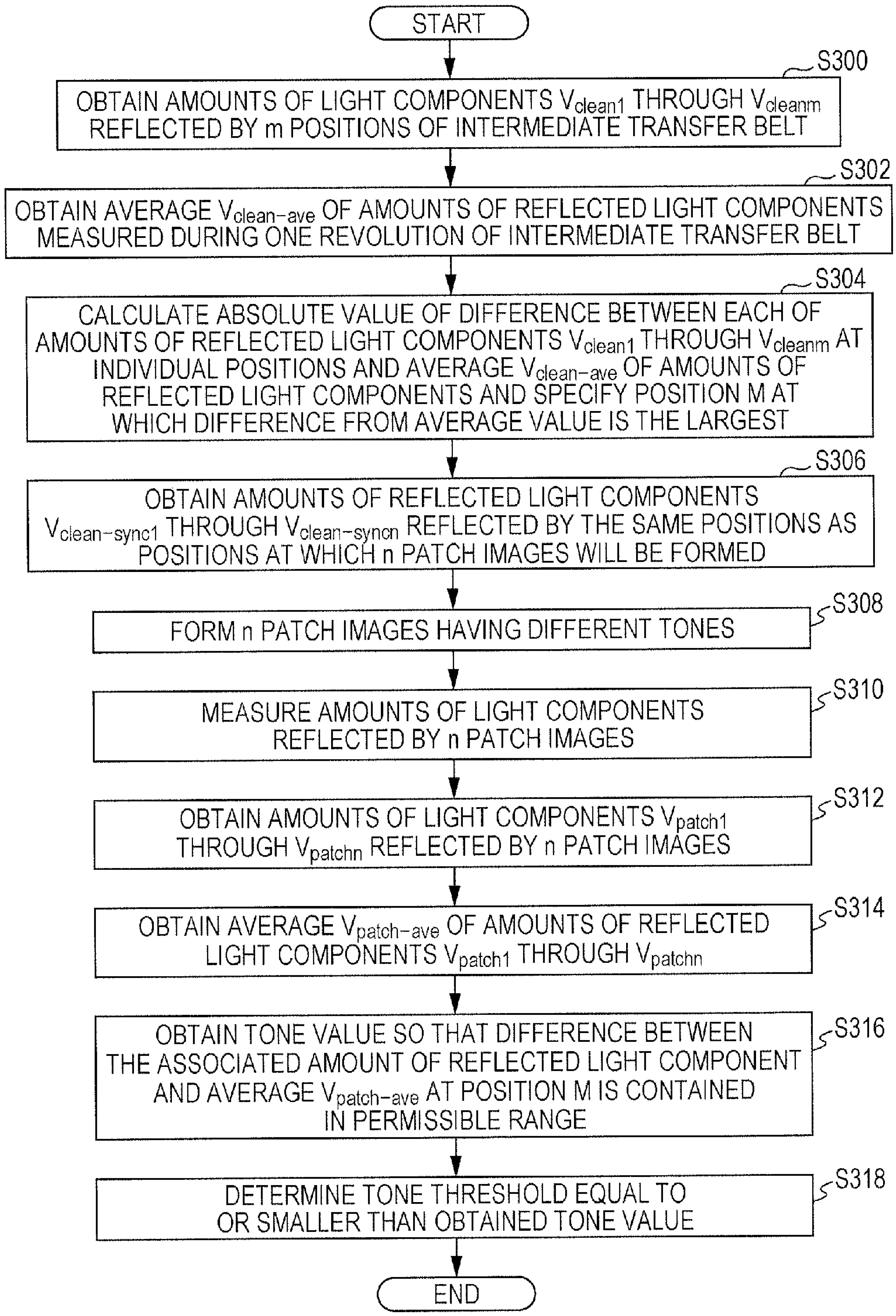


FIG. 9B

ΔV_{clean} (V)	TONE THRESHOLD
A TO B	40%
B TO C	30%
C TO D	20%
<D	10%

NOTE: D<C<B<A

FIG. 10


START
S300
OBTAIN AMOUNTS OF LIGHT COMPONENTS V_{clean1} THROUGH V_{cleanm} REFLECTED BY m POSITIONS OF INTERMEDIATE TRANSFER BELT
S302
OBTAIN AVERAGE $V_{clean-ave}$ OF AMOUNTS OF REFLECTED LIGHT COMPONENTS MEASURED DURING ONE REVOLUTION OF INTERMEDIATE TRANSFER BELT
S304
CALCULATE ABSOLUTE VALUE OF DIFFERENCE BETWEEN EACH OF AMOUNTS OF REFLECTED LIGHT COMPONENTS V_{clean1} THROUGH V_{cleanm} AT INDIVIDUAL POSITIONS AND AVERAGE $V_{clean-ave}$ OF AMOUNTS OF REFLECTED LIGHT COMPONENTS AND SPECIFY POSITION M AT WHICH DIFFERENCE FROM AVERAGE VALUE IS THE LARGEST
S306
OBTAIN AMOUNTS OF REFLECTED LIGHT COMPONENTS $V_{clean-sync1}$ THROUGH $V_{clean-syncn}$ REFLECTED BY THE SAME POSITIONS AS POSITIONS AT WHICH n PATCH IMAGES WILL BE FORMED
S308
FORM n PATCH IMAGES HAVING DIFFERENT TONES
S310
MEASURE AMOUNTS OF LIGHT COMPONENTS REFLECTED BY n PATCH IMAGES
S312
OBTAIN AMOUNTS OF LIGHT COMPONENTS V_{patch1} THROUGH V_{patchn} REFLECTED BY n PATCH IMAGES
S314
OBTAIN AVERAGE $V_{patch-ave}$ OF AMOUNTS OF REFLECTED LIGHT COMPONENTS V_{patch1} THROUGH V_{patchn}
S316
OBTAIN TONE VALUE SO THAT DIFFERENCE BETWEEN THE ASSOCIATED AMOUNT OF REFLECTED LIGHT COMPONENT AND AVERAGE $V_{patch-ave}$ AT POSITION M IS CONTAINED IN PERMISSIBLE RANGE
S318
DETERMINE TONE THRESHOLD EQUAL TO OR SMALLER THAN OBTAINED TONE VALUE
END

DENSITY DETECTION APPARATUS AND METHOD AND IMAGE FORMING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2012-025518 filed Feb. 8, 2012.

BACKGROUND

(i) Technical Field

The present invention relates to a density detection apparatus and method and an image forming apparatus.

(ii) Related Art

In order to correct the density of images formed by an image forming apparatus, a technique for forming density detection images on an image carrier and for detecting the density levels of the density detection images is known.

SUMMARY

According to an aspect of the invention, there is provided a density detection apparatus including: an image forming unit that forms plural density detection images having different area ratios on an image carrier; a measuring unit that measures an amount of light reflected by the image carrier or the plural density detection images formed on the image carrier; a storage unit that stores, as reference values, amounts of plural light components reflected by the image carrier during one revolution of the image carrier, and that also stores a representative value of the amounts of light components reflected by the image carrier during one revolution of the image carrier; a determining unit that determines a threshold for the area ratios of the plural density detection images on the basis of a variation among the reference values; and a density obtaining unit that obtains, for a density detection image having an area ratio which exceeds the threshold, a density level corresponding to the area ratio of the density detection image by using the amount of light reflected by the density detection image and the representative value, and that obtains, for a density detection image having an area ratio which is equal to or smaller than the threshold, a density level corresponding to the area ratio of the density detection image by using the amount of light reflected by the density detection image, the associated reference value, and the representative value.

BRIEF DESCRIPTION OF THE DRAWINGS

An exemplary embodiment of the present invention will be described in detail based on the following figures, wherein:

FIG. **1** is a schematic view illustrating an example of the configuration of an image forming apparatus according to an exemplary embodiment of the invention;

FIG. **2** schematically illustrates an example of the configuration of a light amount detector;

FIG. **3** is a block diagram illustrating the electrical configuration of the image forming apparatus shown in FIG. **1**;

FIG. **4** schematically illustrates an example of density detection images formed on an image carrier;

FIG. **5** illustrates a change in a detection signal output from a light amount detector over time;

FIG. **6** is a flowchart illustrating a processing routine of density correction processing;

FIG. **7** illustrates a change in an output signal, output from a light amount detector, indicating the amount of light measured during one revolution of an intermediate transfer belt;

FIG. **8** is a flowchart illustrating a processing routine of threshold determining processing;

FIGS. **9**A and **9**B respectively illustrate ΔV_{clean} and a table indicating the association between ΔV_{clean} and a threshold (tone threshold) of the area ratio; and

FIG. **10** is a flowchart illustrating another processing routine of threshold determining processing.

DETAILED DESCRIPTION

An exemplary embodiment of the present invention will be described below in detail with reference to the accompanying drawings.

Image Forming Apparatus

An example of the configuration of an image forming apparatus will be discussed below.

The image forming apparatus is an electrophotographic image forming apparatus that forms images on paper by using an electrophotographic developer including toner. In this exemplary embodiment, a so-called tandem, intermediate-transfer image forming apparatus will be described. The image forming apparatus may be of any type as long as it forms density detection images on an image carrier, detects the density levels of the density detection images, and corrects image density levels. The configuration of the image forming apparatus is not restricted to that described in this exemplary embodiment.

FIG. **1** is a schematic view illustrating an example of the configuration of the image forming apparatus according to this exemplary embodiment. FIG. **2** schematically illustrates an example of the configuration of a light amount detector. FIG. **3** is a block diagram illustrating the electrical configuration of the image forming apparatus shown in FIG. **1**.

As shown in FIGS. **1** and **3**, the image forming apparatus of this exemplary embodiment includes an operation display unit **10**, an image reader **20**, an image forming unit **30**, a sheet supply unit **40**, a sheet discharge unit **50**, a light amount detector **60**, a position detector **70**, a communication unit **80**, a storage unit **90**, and a controller **100**. The image forming unit **30**, the sheet supply unit **40**, and the sheet discharge unit **50** are disposed in the order of the sheet supply unit **40**, the image forming unit **30**, and the sheet discharge unit **50**, along a sheet transport path indicated by the broken line in FIG. **1**.

The light amount detector **60** and the position detector **70** are disposed at a position on the exterior side of an image carrier, which forms the image forming unit **30**, such that they oppose the image carrier. In this exemplary embodiment, the image carrier is an intermediate transfer belt **36**, which will be discussed later. The light amount detector **60** is disposed on the downstream side of an image forming unit **32** with respect to the direction in which the intermediate transfer belt **36** is moved, and measures amounts of light reflected by density detection images which are formed on the intermediate transfer belt **36** by using the image forming unit **30**.

The controller **100** is constituted as a computer that controls the entire image forming apparatus and executes various operations. The controller **100** includes a central processing unit (CPU) **100**A, a read only memory (ROM) **100**B in which various programs are stored, a random access memory (RAM) **100**C used as a work area when programs are executed, a non-volatile memory **100**D in which various items of information are stored, and an input/output interface (I/O) **100**E. The CPU **100**A, the ROM **100**B, the RAM **100**C, the non-volatile memory **100**D, and the I/O **100**E are connected to one another via a bus **100**F.

The operation display unit **10**, the image reader **20**, the image forming unit **30**, the sheet supply unit **40**, the sheet discharge unit **50**, the light amount detector **60**, the position detector **70**, the communication unit **80**, and the storage unit **90** are connected to the I/O **100**E of the controller **100**. The controller **100** controls the operation display unit **10**, the image reader **20**, the image forming unit **30**, the sheet supply unit **40**, the sheet discharge unit **50**, the light amount detector **60**, the position detector **70**, the communication unit **80**, and the storage unit **90**.

The controller **100** obtains detection results output from the light amount detector **60** and the position detector **70** as detection signals. The image forming apparatus includes plural transport rollers **46** which are disposed along the sheet transport path indicated by the broken line shown in FIG. **1**. The plural transport rollers **46** are driven by a drive mechanism (not shown), and thereby transports a sheet in accordance with an image forming operation.

The operation display unit **10** includes various buttons, such as a start button and a numeric keypad, and a touch panel used for displaying various screens, such as a warning message screen and a setting screen. With this configuration, the operation display unit **10** receives operations performed by a user and displays various items of information for a user. The image reader **20** includes a charge coupled device (CCD) image sensor, an image reading device that optically reads images formed on paper, a scanning mechanism for scanning paper, etc. With this configuration, the image reader **20** reads images formed on a document which is placed on the image reader **20** and then generates image information.

The image forming unit **30** forms images on paper by using an electrophotographic system. The image forming unit **30** includes an image forming unit **32**K that forms black (K) toner images, an image forming unit **32**C that forms cyan (C) toner images, an image forming unit **32**M that forms magenta (M) toner images, and an image forming unit **32**Y that forms yellow (Y) toner images. The image forming unit **30** includes the intermediate transfer belt **36**, a second transfer device **38**, and a fixing device **39**. The intermediate transfer belt **36** is wound on plural rollers **34** such that it is moved in the direction indicated by the arrow B in FIG. **1**. The second transfer device **38** simultaneously transfers toner images on the intermediate transfer belt **36** onto paper. The fixing device **39** fixes toner images transferred onto paper.

The image forming units **32**K, **32**C, **32**M, and **32**Y are disposed in the order shown in FIG. **1** so that a Y toner image, an M toner image, a C toner image, and a K toner image are formed on the intermediate transfer belt **36** in this order when the intermediate transfer belt **36** is moved in the direction indicated by the arrow B in FIG. **1**. Hereinafter, the image forming units **32**K, **32**C, **32**M, and **32**Y will be simply referred to as “image forming unit **32**” or “image forming units **32**” unless it is necessary to distinguish between the individual colors. The image forming units **32** each includes a photoconductor drum, a charging device, an exposure device, a developing device, a transfer device, a cleaning device, etc. The photoconductor drums are formed such that they are rotated in the direction indicated by the arrows.

The rollers **34** include a driver roller **34**A, a back support roller **34**B, a tension application roller **34**C, and a driven roller **34**D. The intermediate transfer belt **36** is wound on the driver roller **34**A, the back support roller **34**B, the tension application roller **34**C, and the driven roller **34**D. Hereinafter, these rollers **34** will be simply referred to as “plural rollers **34**” unless it is necessary to distinguish between them. The plural rollers **34** are driven by a drive mechanism (not shown). The drive roller **34**A is driven to rotate by the drive mechanism, thereby causing the intermediate transfer belt **36** to move at a predetermined speed in the direction indicated by the arrow B shown in FIG. **1**. The tension application roller **34**C is moved outward by the drive mechanism, thereby applying a predetermined tension to the intermediate transfer belt **36**.

The image forming unit **30** forms images by the following procedure.

The image forming unit **32**K transfers a K toner image onto the intermediate transfer belt **36** in the following manner. The charging device charges the photoconductor drum. The exposure device then exposes the charged photoconductor drum to light corresponding to a K image, thereby forming an electrostatic latent image corresponding to the K image on the photoconductor drum. The developing device then develops the electrostatic latent image formed on the photoconductor drum by using a K toner, thereby forming a K toner image. The transfer device transfers the K toner image formed on the photoconductor drum onto the intermediate transfer belt **36**.

Similarly, the image forming unit **32**C transfers a C toner image onto the intermediate transfer belt **36**. The image forming unit **32**M transfers an M toner image onto the intermediate transfer belt **36**. The image forming unit **32**Y transfers a Y toner image onto the intermediate transfer belt **36**. The K, C, M, and Y toner images are superposed on one another, thereby forming “superposed toner images”. The second transfer device **38** simultaneously transfers the superposed toner images on the intermediate transfer belt **36** onto paper. The fixing device **39** heats and pressurizes the superposed images transferred on paper, thereby fixing the superposed images on paper.

The sheet supply unit **40** includes a sheet housing section **42**, a supply mechanism for supplying sheets from the sheet housing section **42** to the image forming unit **30**, etc. The supply mechanism includes a feeder roller **44** that feeds sheets from the sheet housing section **42** and transports rollers **46**. Plural sheet housing sections **42** are provided in accordance with the types and the sizes of sheets. The sheet supply unit **40** feeds sheets from one of the sheet housing sections **42** and supplies the sheets to the image forming unit **30**. The sheet discharge unit **50** includes a discharge section **54** to which sheets are discharged, a discharge mechanism for discharging sheets onto the discharge section **54**, etc.

The light amount detector **60** is an optical sensor that irradiates a subject to be detected with detection light and that also detects an amount of light reflected by the subject. A detection signal output from the light amount detector **60** represents an amount of light reflected by the subject. The subject is the intermediate transfer belt **36** on which no density detection image is formed, or a density detection image group G formed on the intermediate transfer belt **36** (see FIG. **7**). Details of density correction processing and density detection images will be given later.

As shown in FIG. **2**, the light amount detector **60** includes a light emitting element **62** that emits detection light to be applied to a subject and a light receiving element **64** that receives light reflected by the subject. As the light emitting element **62**, a light emitting element that emits light in a visible region or in an infrared region, such as a light emitting diode (LED), is used. As the light receiving element **64**, a light receiving element having sensitivity to detection light, such as a photodiode (PD), is used. The light emitting element **62** is driven to be lit ON or OFF by a driver (not shown) in accordance with a control signal output from the controller **100**. The light receiving element **64** is connected to the controller **100** via an analog-to-digital (A/D) converter (not shown) and outputs a detection signal which is converted to a digital signal by the A/D converter to the controller **100**.

The light emitting element **62** and the light receiving element **64** are supported by a support member (not shown) and are housed in a housing **61**. In the example shown in FIG. **2**, the housing **61** includes an optical waveguide **66** that guides detection light and an optical waveguide **68** that guides reflected light. Detection light emitted from the light emitting element **62** propagates within the optical waveguide **66** and is applied to the density detection image group G formed on the intermediate transfer belt **36**. Light reflected by the density detection image group G propagates within the optical waveguide **68** and is received by the light receiving element **64**. In this exemplary embodiment, the light emitting element **62** and the light receiving element **64** are disposed such that light obtained as a result of being regularly reflected by the density detection image group G irradiated with detection light is received by the light receiving element **64**. That is, the light amount detector **60** is a regular reflection optical sensor.

The position detector **70** is a position sensor that detects a reference mark M (see FIG. **4**) attached on the intermediate transfer belt **36** so as to detect a predetermined reference position. When forming an image, the position detector **70** outputs a position detection signal, which serves as a reference to starting an image forming operation. The position detector **70**, as well as the light amount detector **60**, includes a light emitting element and a light receiving element, and irradiates the intermediate transfer belt **36** with light and also receives light reflected by the surface of the mark M, thereby detecting the position of the intermediate transfer belt **36**. In density correction processing, which will be discussed later, various operations are performed on the basis of the position detection signal as a reference to starting an image forming operation.

The communication unit **80** is an interface through which the image forming apparatus communicates with an external apparatus via a wired or wireless communication line. The communication unit **80** receives print parameters including print attributes, such as the number of pages and the number of print copies, together with print instructions and image information concerning electronic documents. The storage unit **90** includes a storage device, such as a hard disk, and stores therein various data, such as log data, and a control program.

In this exemplary embodiment, a description will be given, assuming that a control program of the density correction processing, which will be discussed later, is stored in the storage unit **90** in advance. The control program is read and executed by the CPU **100**A. The control program may be stored in another storage device, such as the ROM **100**B. In this exemplary embodiment, in the storage unit **90**, the association between ΔV_{clean}, which is a variation range of the amount of reflected light V_{clean}, which will be discussed later, and the tone threshold is stored as a table in the storage unit **90** in advance.

Various drives may be connected to the controller **100**. Various drives are devices that read and write data from and into computer-readable portable recording media, such as flexible disks, magneto-optical discs, compact disc (CD)-ROMs. If various drives are provided, a control program may be recorded on a portable recording medium, and may be read and executed by using a drive corresponding to the portable recording medium.

Density Detection Images

Density detection images will be discussed below.

FIG. **4** schematically illustrates an example of density detection images formed on an image carrier. As shown in FIG. **4**, the density detection image group G includes plural density detection images P (hereinafter referred to as "patch images P"). The plural patch images Pare toner images formed of one specific color, e.g., K. The plural patch images P are formed linearly on the intermediate transfer belt **36** in the direction in which the intermediate transfer belt **36** is moved (in the direction indicated by the arrow B in FIG. **4**). That is, an image group including an array of the plural patch images P is the density detection image group G. The density detection image group G is formed such that it is contained within a length L corresponding to one revolution of the intermediate transfer belt **36**. The length L corresponding to one revolution of the intermediate transfer belt **36** is specified by the reference mark M on the intermediate transfer belt **36**.

One patch image P is an image formed at a predetermined ratio of the area of the image to a predetermined area. In this exemplary embodiment, the plural patch images P have different area ratios. The plural patch images P are aligned such that the area ratios are increased or decreased in the direction in which plural patch images P are aligned. The area ratio of the patch image P is represented by a toner coverage ratio per unit area, e.g., 60%. When the coverage ratio is 100%, the patch image P is a solid color image. When the area ratio is 0%, the patch image P is colorless. In this example, the density detection image group G includes twelve patch images P. The area ratios of the twelve patch images P are decreased monotonically from 100% to 0% from the left side to the right side of FIG. **4**.

Since the area ratios of the plural patch images P are changed in a stepwise manner, they may be referred to as "tone levels" or "tone values". The threshold of the area ratio may be referred to as a "tone threshold".

When the intermediate transfer belt **36** is moved in the direction indicated by the arrow B shown in FIG. **4**, the position detector **70** detects the reference mark M on the intermediate transfer belt **36**, thereby detecting a predetermined reference position. The light amount detector **60** detects the amount of light reflected by the density detection image group G formed on the intermediate transfer belt **36**. In this case, the amounts of light components reflected by the patch images P are detected in order from a patch image P having a higher area ratio to a patch image P having a lower area ratio.

FIG. **5** illustrates a change in a detection signal output from the light amount detector **60** over time. In the example shown in FIG. **5**, density detection images contained within a length L corresponding to one revolution have the same area ratio. As shown in FIG. **5**, the amount of light detected by the light amount detector **60** changes in accordance with the movement of the intermediate transfer belt **36**. When the area ratio (patch tone) is 0%, the amount of light reflected by the intermediate transfer belt **36** is detected. When the area ratio is 20%, 40%, or 60%, the amount of light reflected by the toner images having the corresponding area ratio is detected. As the area ratio is increased, as 0%, 20%, 40%, and 60%, a change in the amount of light is decreased.

The amount of reflected light detected by the light amount detector **60** varies due to various factors, such as differences in individual optical sensors, the state in which an optical sensor is installed, the presence of an unclean area in the optical path of the optical sensor, and temperature characteristics of the optical sensor. Generally, a change in the amount of reflected light due to the above-described factors is corrected by using the amount of light V_{clean} reflected by the image carrier as a reference value. Correction by using the amount of light V_{clean} is effective particularly in a regular-reflection optical sensor.

However, if the state of the surface of the image carrier is changed, the amount of reflected light V_{clean}, which is a reference value, is also changed, which makes it difficult to obtain the correct image density. For example, flaws may occur on the surface of the image carrier over time, chemical substances generated in the image forming apparatus may become attached to the surface of the image carrier, or if the image carrier is a belt wound on plural rollers, cockles may occur on the surface of the belt depending on the tension applied to the belt, or vibrations may occur when specific portions of the belt strike the rollers.

In the example shown in FIG. **5**, when the area ratio of the density detection images is 0%, the amounts of reflected light components detected by the light amount detector **60** (i.e., a detection signal output from the light amount detector **60**) sharply fluctuate in accordance with the rotation of the intermediate transfer belt **36** due to the surface state of the intermediate transfer belt **36**. As the area ratio is increased, the toner coverage ratio is also increased, which makes fluctuation in the detection signal output from the light amount detector **60** less noticeable. However, a sharp fluctuation in the amount of reflected light when the area ratio is 0% is still influential. In this manner, if the amount of light reflected by the intermediate transfer belt **36** sharply fluctuates due to a change in the surface state of the intermediate transfer belt **36**, the amounts of light components reflected by the density detection images also vary, which makes it difficult to obtain the correct image density.

In this exemplary embodiment, every time density correction processing is performed, the threshold for the area ratio of a density detection image is determined depending on whether a change in the amount of reflected light is within a permissible range. For example, the peak in the area A indicated by the broken line becomes smaller as the area ratio is higher, and it is almost unnoticeable when the area ratio is 40%. Accordingly, the threshold is set to be 40%. In this manner, the threshold for the area ratio of a density detection image is set in accordance with the surface state of the image carrier, i.e., in accordance with the degree of the influence of a change in the amount of reflected light V_{clean}, which is the reference value.

If the area ratio of a density detection image is equal to or smaller than the threshold (if the density detection image has a smaller area ratio), the image density of the density detection image is determined in accordance with the surface state of the intermediate transfer belt **36**. Then, density correction processing is performed by using the determined image density. As shown in FIG. **4**, the density detection image group G is constituted by plural patch images P having different area ratios. Accordingly, the above-described threshold determining processing is performed for each patch image P.

Density Correction Processing

Density correction processing will now be described below.

In the image forming apparatus, density correction processing is started when predetermined conditions are satisfied. During the execution of density correction processing, a normal image forming operation is not performed. In this exemplary embodiment, the number of image forming operations is counted, and when the number of image forming operations exceeds a restricted number, density correction processing is started. The conditions for starting density correction processing may be other conditions. For example, when a predetermined period has elapsed, density correction processing may be started.

FIG. **6** is a flowchart illustrating a processing routine of density correction processing. FIG. **7** illustrates a change in an output signal, output from a light amount detector, indicating the amount of light reflected by an intermediate transfer belt corresponding to a length of one revolution of the intermediate transfer belt. FIG. **8** is a flowchart illustrating a processing routine of threshold determining processing. FIGS. **9**A and **9**B respectively illustrate ΔV_{clean} and a table indicating the relationship (association) between ΔV_{clean} and the threshold (tone threshold) of the area ratio.

The density correction processing, and the threshold determining processing, which is a subroutine of the density correction processing, are executed by the CPU **100**A of the controller **100**. In the density correction processing, if the area ratio of a density detection image is equal to or smaller than the threshold, the density of the density detection image is determined in accordance with the surface state of the intermediate transfer belt **36**. In this manner, the correct density of the density detection image is obtained. In this exemplary embodiment, the density detection image group G includes n patch images P_1 through P_n having different area ratios. The procedure for the density correction processing will be described below more specifically.

In step S**100**, the controller **100** instructs the light amount detector **60** to measure the amount of light reflected by the intermediate transfer belt **36** corresponding to a length of one revolution of the intermediate transfer belt **36**. As during the execution of an image forming operation, the intermediate transfer belt **36** is moving in the direction indicated by the arrow B shown in FIG. **4** at a predetermined speed. While the intermediate transfer belt **36** is rotating through one revolution, the light amount detector **60** measures the amount of light reflected by the intermediate transfer belt **36**. The light amount detector **60** then outputs a detection signal indicating an amount of reflected light to the controller **100**.

In step S**102**, the amount of light V_{clean} reflected by the intermediate transfer belt **36** during one revolution of the intermediate transfer belt **36** is obtained. As shown in FIG. **7**, the amount of light V_{clean} reflected by the intermediate transfer belt **36** during one revolution of the intermediate transfer belt **36** is obtained. "Period for which the amount of light reflected by the intermediate transfer belt **36** is measured" shown in FIG. **7** corresponds to one revolution of the intermediate transfer belt **36**. The amount of light V_{clean} is used as the reference value.

Then, in step S**104**, threshold determining processing for determining the threshold of density detection images is executed. The threshold determining processing will be described in detail with reference to FIG. **8**. In step S**200**, the difference ΔV_{clean} between the maximum value and the minimum value of the amounts of light components V_{clean} measured during one revolution of the intermediate transfer belt **36** is obtained (see FIG. **9**A). Then, in step S**202**, the tone threshold associated with the obtained difference ΔV_{clean} is obtained.

In this exemplary embodiment, as shown in FIG. **9**B, the association between ΔV_{clean}, which indicates a range of a change in the amount of reflected light V_{clean}, and the tone threshold is stored in advance in the storage unit **90** as a table. For example, when ΔV_{clean} ranges from A to B, the tone threshold is 40%. Accordingly, the tone threshold associated with the difference ΔV_{clean} is obtained by referring to the table read from the storage unit **90**.

Then, in step **S106**, the amounts of light components $V_{clean\text{-}sync1}$ through $V_{clean\text{-}syncn}$ reflected by the same positions of the intermediate transfer belt **36** as the positions at which n patch images P_1 through P_n, respectively, will be formed are obtained. The amounts of light components $V_{clean\text{-}sync1}$ through $V_{clean\text{-}syncn}$ are amounts of light components reflected by the same positions of the intermediate transfer belt **36** as the positions at which n patch images P_1 through P_n will be formed (i.e. one revolution before the n patch images are formed). The amounts of light components $V_{clean\text{-}sync1}$ through $V_{clean\text{-}syncn}$ are used as reference values when correcting the amounts of reflected light components detected by the light amount detector **60**.

Then, in step **S108**, the average $V_{clean\text{-}ave}$ of the amounts of reflected light components measured during one revolution of the intermediate transfer belt **36** is obtained. As shown in FIG. **7**, the amount of reflected light V_{clean} is measured during one revolution of the intermediate transfer belt **36**, and the average $V_{clean\text{-}ave}$ of the amounts of reflected light components V_{clean} measured during this period is used as the representative value.

In step **S110**, the controller **100** instructs the image forming unit **30** to form n patch images P_1 through P_n having different area ratios. In synchronization with the position detection signal output from the position detector **70**, as shown in FIG. **7**, the image forming unit **30** forms a density detection image group G on the intermediate transfer belt **36**. The density detection image group G is an image group including n patch images P_1 through P_n linearly formed on the intermediate transfer belt **36**.

Then, in step **S112**, the controller **100** instructs the light amount detector **60** to detect the amounts of light components reflected by the n patch images P_1 through P_n formed on the intermediate transfer belt **36**. The light amount detector **60** measures the amounts of light components reflected by the n patch images P_1 through P_n while the intermediate transfer belt **36** is rotating through one revolution. The light amount detector **60** outputs a detection signal indicating the measured amounts of light components to the controller **100**. Accordingly, in step **S114**, the controller **100** obtains the amounts of light components V_{patch1} through V_{patchn} reflected by the n patch images P_1 through P_n, respectively.

Then, in step **S116**, the count value "i" of the counter is set to be to 1. The count value "i" is updated every time threshold determining processing is performed for a patch image P. Then, in step **S118**, the i-th patch image P_i is selected. Then, in step **S120**, it is determined whether the area ratio of the selected patch image P_i is equal to or smaller than the threshold. If the result of step **S120** is YES, it means that it is necessary to determine the image density in accordance with the surface state of the intermediate transfer belt **36** since the area ratio of the selected patch image P_i is equal to or smaller than the threshold. The process then proceeds to step **S122**. If the result of step **S120** is NO, it means that the image density may be determined by using a normal technique, and the process then proceeds to step **S128**. In step **S128**, the image density D_{patchi} of the patch image P_i is determined by using the following equation (1).

$$D_{patch}=V_{patch}/V_{clean\text{-}ave}\times K_{std} \quad (1)$$

In step **S122**, the image density $D_{Patchi\ of}$ the patch image P_i is determined by using equation (2) used for correcting the image density. For example, in the example shown in FIG. **7**, patch images P_9 through P_{12} having low area ratios are more susceptible to the influence of a change in the amount of reflected light V_{clean}. Thus, it is necessary to determine the image density in accordance with the surface state of the intermediate transfer belt **36**, and the image density is determine by using the following equation (2).

$$D_{patch}=V_{patch}/[V_{clean\text{-}ave}+\{(V_{clean\text{-}sync}-V_{clean\text{-}ave})\times(C_{in\_th}-C_{in\_patch})/C_{in\_th}\}]\times K_{std} \quad (2)$$

The parameters used in the above-described equations (1) and (2) (some of them have been already discussed) are defined as follows.

D_{patch} density of patch image

V_{patch}: amount of light reflected by patch image

$V_{clean\text{-}ave}$ average of amounts of reflected light components measured during one revolution of intermediate transfer belt (representative value)

$V_{clean\text{-}sync}$ amount of light reflected by the same position of the intermediate transfer belt as the position at which a patch image will be formed (one revolution before the patch image will be formed) (reference value)

C_{in_patch}: area ratio of patch image

C_{in_th}: threshold of area ratio (tone threshold)

K_{std}: normalized coefficient (coefficient for rounding division results to integers (0 through 255, 0 through 1023, etc.))

In equation (2), if $C_{in\_patch}=0$, $V_{patch}/V_{clean\text{-}sync}$ is used. If $C_{in\_patch}=C_{in\_th}$, $V_{patch}/V_{clean\text{-}ave}$ is used. If C_{in_patch} is greater than 0 and smaller than C_{in_th}, the density levels of patch images are proportionally allocated.

Then, in step **S124**, it is determined whether the count value "i" is smaller than n. If the result of step **S124** is YES, it means that there is a patch image P which has not been subjected to **S120** (whether the area ratio is equal to or smaller than the threshold). Thus, the process returns to step **S118**. If the result of step **S124** is NO, it means that step **S120** has been performed for all the patch images P. The process then proceeds to step **S126**.

In step **S126**, density correction processing corresponding to the determined image density D_{patchi} is performed, and the processing routine is completed. In the density correction processing, the correction of the image density is performed on the basis of the image density D_{patchi} of the i-th patch image D_{patchi} so that the output image density of an output image approximates the input image density of an input image (target value).

Modified Examples

In the above-described exemplary embodiment, a table prepared in advance is used for determining the threshold of the area ratio. However, the threshold of the area ratio may be determined in another manner. For example, the amounts of light components reflected by density detection images formed on an image carrier may be actually measured, and the threshold of the area ratio may be determined on the basis of the measurement results. FIG. **10** is a flowchart illustrating another processing routine of threshold determining processing.

In step **S300**, the amounts of light components V_{clean1} through V_{cleanm} reflected by m positions of the intermediate transfer belt **36** are obtained. Then, in step **S302**, the average value $V_{clean\text{-}ave}$ of the amounts of reflected light components measured during one revolution of the intermediate transfer belt **36** is obtained. Then, in step **S304**, the absolute value of the difference between the average value $V_{clean\text{-}ave}$ and each of the amounts of light components V_{clean1} through V_{cleanm} at the m positions (i.e., the difference from the average value $V_{clean\text{-}ave}$) is calculated, and the position M at which the difference from the average value $V_{clean\text{-}ave}$ is the largest is specified. For example, as in the area A in FIG. **5**, the position

M at which a variation in the amount of reflected light caused by the surface state of the intermediate transfer belt **36** is the largest is specified.

Then, in step S**306**, the amounts of light components $V_{clean\text{-}sync1}$ through $V_{clean\text{-}syncn}$ reflected by the positions at which the n patch images P_1 through P_n are formed are obtained. In the above-described exemplary embodiment, as shown in FIGS. **4** through **7**, the density detection image G including patch images having area ratios from 0% to 100% are formed. In this modified example, however, only patch images P having smaller area ratios (low tones), e.g., 60% or lower, which may be influenced by a change in the amount of reflected light caused by the surface state of the intermediate transfer belt **36**, may be formed.

Then, in step S**308**, the controller **100** instructs the image forming unit **30** to form n patch images P_1 through P_n having different area ratios. The image forming unit **30** then forms a density detection image group G including n patch images P_1 through P_n linearly arranged on the intermediate transfer belt **36**.

Then, in step S**310**, the controller **100** instructs the light amount detector **60** to detect the amounts of light components reflected by the n patch images P_1 through P_n formed on the intermediate transfer belt **36**. The light amount detector **60** measures the amounts of light components reflected by the n patch images P_1 through P_n while the intermediate transfer belt **36** is rotating through one revolution. The light amount detector **60** outputs a detection signal indicating the measured amounts of light components to the controller **100**. Accordingly, in step S**312**, the controller **100** obtains the amounts of light components V_{patch1} through V_{patchn} reflected by the n patch images P_1 through P_n, respectively.

Then, in step S**314**, the average value $V_{patch\text{-}ave}$ of the amounts of light components V_{patch1} through V_{patchn} is obtained. Then, in step S**316**, the area ratio is determined so that the difference between the average value $V_{patch\text{-}ave}$ and the associated amount of light component V_{patch} at the position M is contained in a permissible range. For example, in the example shown in FIG. **5**, 40%, which makes a change in the amount of light unnoticeable, is determined as the area ratio so that the difference between the average value $V_{patch\text{-}ave}$ and the corresponding amount of light component is contained in the permissible range. Then, in step S**118**, the area ratio is determined as the tone threshold. The processing routine is then completed.

In the above-described exemplary embodiment, the association between ΔV_{clean}, which indicates a range of a change in the amount of reflected light V_{clean}, and the tone threshold is stored in a table in advance. Alternatively, the association between ΔV_{clean} and the tone threshold may be obtained when necessary. For example, when the surface state of an image carrier, i.e., an intermediate transfer belt, is changed, the association between ΔV_{clean} and the tone threshold may be obtained. More specifically, after the image carrier is replaced by a new one, or after maintenance of the members contained in a transfer apparatus is performed, the above-described association may be regularly obtained in accordance with the condition of the use of the image carrier.

In the above-described exemplary embodiment, the amounts of light components $V_{clean\text{-}sync1}$ through $V_{clean\text{-}syncn}$ reflected by the same positions of the intermediate transfer belt **36** as the positions at which n patch images P_1 through P_n will be formed (one revolution before the n patch images will be formed) are obtained. Alternatively, the amounts of light components $V_{clean\text{-}sync1}$ through $V_{clean\text{-}syncn}$ at a time several revolutions before the n patch images will be formed may be obtained. Additionally, after the amounts of light components reflected by the patch images P are measured, the patch images may be erased, and then, the amount of light reflected by the intermediate transfer belt **36** may be obtained. However, since the surface state of the image carrier changes momentarily, the amount of light reflected by the intermediate transfer belt **36** may preferably be obtained in a short period of time after the amounts of light components reflected by the patch images P are measured.

In the above-described exemplary embodiment, the average value $V_{clean\text{-}ave}$ of the amounts of reflected light components V_{clean} measured during one revolution of the intermediate transfer belt **36** is used as the representative value of the amounts of reflected light components. However, any value which represents the amounts of reflected light components for one revolution of the intermediate transfer belt **36** may be used. For example, the median or the mode may be used as the representative value.

The configurations of the density detection apparatus and the image forming apparatus discussed in the above-described exemplary embodiment are only examples, and may be changed without departing from the spirit of the invention. For example, the image carrier may be replaced by a drum, and the orders of step numbers of the individual flowcharts may be changed.

The foregoing description of the exemplary embodiment and the modified examples of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiment and the modified examples chosen and described in order to best explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to understand the invention for various embodiments and with the various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.

What is claimed is:

1. A density detection apparatus comprising:

an image forming unit configured to form a plurality of density detection images having different area ratios on an image carrier;

a measuring unit configured to measure a first amount of light reflected by the image carrier before the plurality of density detection images are formed thereon and configured to measure a second amount of light reflected by the plurality of density detection images formed on the image carrier;

a storage unit configured to store, as a reference value, the first amount of light reflected by the image carrier during one revolution of the image carrier before the plurality of density detection images are formed thereon;

a determining unit configured to determine, each time a density correction processing is started, a threshold corresponding to the plurality of density detection images on the basis of the reference value; and

a density obtaining unit configured to obtain, based on the determined threshold, a respective plurality of density levels corresponding to the plurality of density detection images,

wherein the determining unit is configured to specify a position of the image carrier at which a difference between the reference value and an average value of the first amount of light is large during one revolution of the image carrier, and configured to cause the density detection apparatus to repeat the density correction processing by (i) causing the image forming unit to form the plurality of density detection images having different area ratios on the image carrier, (ii) causing the measuring unit to measure the second amount of light reflected by the plurality of density detection images formed on the image carrier, and (iii) determining the threshold corresponding to the plurality of density detection images so that a change in the amount of light reflected by one of the density detection images located at the specified position will be equal to or smaller than a predetermined permissible value.

2. The density detection apparatus according to claim **1**, wherein the determining unit is configured to determine the threshold corresponding to the plurality of density detection images on the basis of a range of variation of the reference value.

3. An image forming apparatus comprising:

an image forming unit configured to form a plurality of density detection images having different area ratios on an image carrier;

a measuring unit configured to measure a first amount of light reflected by the image carrier before the plurality of density detection images are formed thereon and configured to measure a second amount of light reflected by the plurality of density detection images formed on the image carrier;

a storage unit configured to store, as a reference value, the first amount of light reflected by the image carrier during one revolution of the image carrier before the plurality of density detection images are formed thereon;

a determining unit configured to determine, each time a density correction processing is started, a threshold corresponding to the plurality of density detection images on the basis of the reference value;

a density obtaining unit configured to obtain, based on the determined threshold, a respective plurality of density levels corresponding to the plurality of density detection images; and

a correcting unit configured to correct an output image density on the basis of the respective plurality of density levels corresponding to the plurality of density detection images,

wherein the determining unit is configured to specify a position of the image carrier at which a difference between the reference value and an average value of the first amount of light is large during one revolution of the image carrier, and configured to cause the density detection apparatus to repeat the density correction processing by (i) causing the image forming unit to form the plurality of density detection images having different area ratios on the image carrier, (ii) causing the measuring unit to measure the second amount of light reflected by the plurality of density detection images formed on the image carrier, and (iii) determining the threshold corresponding to the plurality of density detection images so that a change in the amount of light reflected by one of the density detection images located at the specified position will be equal to or smaller than a predetermined permissible value.

4. The image forming apparatus of claim **3**, wherein the determining unit is configured to determine the threshold corresponding to the plurality of density detection images on the basis of a range of variation of the reference value.

5. A density detection method comprising:

measuring a first amount of light reflected by an image carrier before a plurality of density detection images having different area ratios are formed on the image carrier and measuring a second amount of light reflected by the plurality of density detection images formed on the image carrier;

storing, as a reference value, the first amount of light reflected by the image carrier during one revolution of the image carrier before the plurality of density detection images are formed thereon;

determining, each time a density correction processing is started, a threshold corresponding to the plurality of density detection images on the basis of the reference value; and

obtaining, based on the determined threshold, a respective plurality of density levels corresponding to the plurality of density detection images,

wherein the determining further comprises specifying a position of the image carrier at which a difference between the reference value and an average value of the first amount of light is large during one revolution of the image carrier, and causing repetition of the density correction processing by (i) causing formation of the plurality of density detection images having different area ratios on the image carrier, (ii) causing measurement of the second amount of light reflected by the plurality of density detection images formed on the image carrier, and (iii) determining the threshold corresponding to the plurality of density detection images so that a change in the amount of light reflected by one of the density detection images located at the specified position will be equal to or smaller than a predetermined permissible value.

6. The density detection method of claim **5**, wherein the determining the threshold comprises determining the threshold corresponding to the plurality of density detection images based on a range of variation of the reference value.

* * * * *